DEIS-APPENDIX 6

NOISE MEASUREMENTS AND INFLUENCING FACTORS
FOR
DMT PORTSITE NAVIGATION IMPROVEMENTS
(TRESTLE-CHANNEL ALTERNATIVE)

DEIS APPENDIX 6

Noise Measurements and Influencing Factors
Navigation Improvements,
DeLong Mountain Terminal, Alaska

Introduction

This appendix is intended to provide additional information to readers who are interested in the physical characteristics of sounds and how they are measured. It addresses measurement of sound, sound energy produced by multiple sources, and sound propagation loss rates. Additional information is provided regarding physical and atmospheric conditions that affect various components of sound.

Measuring Sound in Air and Water

Because sound moves differently through air than it does through water, it is measured differently in each medium. Water is denser than air and sound travels about 5 times faster in water than air. The higher density of water is also the reason why sound goes farther underwater than in air. Sound pressure levels (SPL's) are referenced differently due to different pressures in the two mediums. Noise traveling through air is typically measured in decibels (dB) relative to a reference pressure of 20 micro-pascals (μPa), whereas noise traveling through water is measured in dB relative to a much lower reference pressure of 1 μPa. These reference pressures are standards adopted among acoustic researchers. Because the reference pressures that apply to the mediums are not the same, it is inappropriate to make direct comparisons between measurements taken in air and water.

The levels of sounds (in either air or water) are measured on a logarithmic instead of a linear scale. This means, for example, that a sound measured at 80 dB is 10 times more powerful than a sound measured at 70 dB, and a sound measured at 90 dB is 100 times more powerful than the sound that was measured at 70 dB. But, at the same time, the 90 dB sound is only 10 times more powerful than the 80 dB sound.

Combining Multiple Sound Sources

When sounds are being generated in the same general area by more than one source, either at the same levels or at different levels, it is possible to determine the total contribution of these sources to the noise environment. As mentioned earlier, since sound is measured on a logarithmic scale, it is not possible to get the combined effect by simply adding the measured values together (i.e. 180 dB +180 dB $\neq$ 360 dB). Two examples are provided below showing how the total overall noise levels are derived from sounds generated at the same level, and from sounds generated at different levels.

(a) <u>Combining sounds generated at the same level.</u> Adding multiple sources of the same sound pressure level (SPL) is based on the following formula:

SPL_{total} = (10 * log (# of sources))+SPL of one source
For instance, 3 tugs operating at 140 dB would be calculated thusly:

SPL_{total} = (10 * log (3))+140 ≅ 145 dB re 1 μPa

If sounds at a 140 dB level were produced by two sources in the same area, the total sound level would be logarithmically calculated to be 143 dB. If the140 dB sounds were generated from five sources in the same area, the total sound level would be 147 dB. If ten sources were each generating a 140 dB sound in the same area, the total sound would be 150 dB. This means that in general, for every 10 sources in the same area generating sounds at the same level, the overall sound level increases by 10 dB.

(b) <u>Combining sounds generated at the different levels.</u> When multiple noise sources generating sounds at different SPLs are present in the same general area, the sound with the highest dB value will essentially "mask" the sounds with lower dB values.

Since dB levels are on a logarithmic scale, it is necessary to understand the relation between the different noise sources. For instance, 160 dB can be written as 10 * log (10^16 / 1) and 140 dB is 10 * log (10^14 / 1). 10^14 is only 1/100th of 10^16. 1/100th = 0.01.

Adding multiple sources of the different SPLs is based on the following formula:

SPL_{total} = (10 * log (1.0 for the higher dB value + the decimal value of the lesser source))+SPL of the higher source

For instance, a 140 dB tug operating in the same area as a 160 dB tub would yield the following:

SPL_{total} = (10 * log (1.0 + .01)) + 160 dB ≅ 160.04 dB re 1 μPa

Likewise, if there were five sources generating sounds at 140 dB in the same area as the source generating the 160 dB sounds, the combined sound would be calculated to be 160.8 dB. One important result of this would be that the combined sounds (at 160.8 dB) would diminish to background levels in approximately the same distance from the sources as the sound with the highest level (160 dB). Therefore, it is a similar situation to adding 1 to 1,000; it does not make very much difference.

Determining Sound Loss Over Distance

The distance needed for sounds generated in water to become equivalent to ambient noise levels is determined in part by the rate at which sound decreases over distance. This rate is termed "spreading loss." The rate at which sounds decrease is based on several factors including bottom composition, bathymetric profile, conflicting noise sources, separation distances between sources, depth of source, and presence of islands or shoals. The rates range from a 3 to 6 dB decrease per doubling of distance and from 10 to 20 dB per 10-fold increase in distance. Assuming a decrease of 20 dB per 10-fold increase in distance, a source level of 140 dB at 1 meter would decrease to 120 dB at 10 meters and 100 dB at 100 meters. If the rate is 10 dB per 10-fold increase in distance then a source level of 140 dB at 1 meter would decrease to 130 dB at 10 meters, 120 dB at 100 meters, 110 dB at 1,000 meters, and 100 dB at 10,000 meters.

Obviously, there is a large difference between the two spreading loss rates. The actual spreading loss experienced is a site-specific value. Values measured at Portsite typically ranged between 15 to 20 dB per 10-fold increase in distance depending on the location where the measurements were taken (nearshore vs. farther offshore). When assessing the distance at which sounds from Portsite would approach ambient levels, the more conservative (i.e. lower) spreading loss terms were applied in order to describe a worst-case scenario.

Factors Influencing Airborne and Underwater Noise Environments at Portsite

Influences on Airborne Noise

With the exception of occasional aircraft noise that is not directly associated with the activities at the Portsite, airborne noise sources near Portsite are generated from near ground level. Factors influencing the airborne noise environment at Portsite include atmospheric conditions, topography, and the water surface. These influencing factors are briefly discussed below.

<u>Atmospheric Conditions.</u> Wind and temperature gradients in the air can cause sounds generated by a given source at Portsite to diminish more quickly upwind, and travel farther downwind of the source. Also, atmospheric absorption by oxygen and nitrogen molecules in the air can have a diminishing effect on higher frequency sounds. This means that low frequency sounds at Portsite will likely travel more efficiently through the air than higher frequency sounds.

During the open water season, wind generates waves and increases background levels of airborne noise. During the spring when ice is present, wind can cause the formation of leads and push pack ice against the edge of shorefast ice to form pressure ridges, also increasing background noise levels. If conditions are right during spring breakup, wind can push sheets of ice against the sheetpile support cells of the existing barge loader, causing ice sheets to pile up and generate noise. This type of ice piling was observed during the Corps of Engineers surveys in June 2000.

<u>Topography.</u> The roughness of the terrain surrounding the DMT can influence how far airborne sounds will travel in the air. The relative flatness of the topography at Portsite

generally means that sounds generated in the air will travel for a greater distance than sounds generated in rough terrain.

Reflective Water Surface. Sounds generated from sources in the air at Portsite typically do not transmit into the water since most airborne sounds generated at ground level are reflected from the water surface. Air to water transmission of sound in the Portsite area would typically occur only with sounds produced by aircraft directly overhead, snowmachines driven over the ice, or at relatively steep angles in a limited area beneath the barge loader.

Seasonal Variations. Weather and seasonal conditions affect the noise in the air due to wind, rain, waves breaking on the beach, ice floes fracturing and colliding, and numerous biological sounds. Sounds generated from Portsite also change based on seasons. When ice has formed and shipping has ceased, noise is present largely from sources on shore. These sources include generators, truck traffic, and other industry related sounds. Additional sound contributions to the environment when ice is present are primarily from snow machines, both on shorefast ice and on shore. During the ice-free season, sounds from port operations on shore are combined with sounds of ore loading and tug boat engines. Additional sources of sound in the ice-free months include four-wheelers and outboard motors.

Influences on Underwater Noise

The underwater noise environment at Portsite is influenced by local physiographic characteristics such as sea ice conditions, wind and waves, bathymetry, and bottom composition. While some of these physiographic features, such as the arrival and departure of sea ice, typically change seasonally, others, such as variations in wind and wave conditions, can change daily. The influences of these characteristics on the underwater noise environment at Portsite are briefly discussed below.

Sea Ice. During the winter, although the surface of the shorefast ice at Portsite may appear flat, the underside can have numerous ridges and variations in thickness, and can even touch the bottom in near shore areas (up to 20-foot depths). As seasons and sea ice conditions change at Portsite, under-ice roughness also changes, affecting how sounds travel under the ice. When the underside is very smooth, sound transmission would be easier, whereas when the under-ice surface is rough, it can interfere with sound transmission and cause it to diminish closer to the source.

The underwater noise environment at Portsite during winter is generally very quiet because the ice is stable and no boats, tugs, or ships are operating in the area. During spring, as leads form and sheets of ice grind against each other, periodic underwater noise events occur. As breakup progresses into late spring, the incidence of noise events increases since the ice sheets are generally free to move against each other. The melting ice can also contribute a “seltzer” (or fizzing) noise to the background noise (Blackwell citing Urick, 1971).

Wind and Waves. Wind at Portsite can also have considerable influence on underwater background noise levels. During the open water season, the increased wave activity created by winds can appreciably increase underwater noise levels. During the time of year that ice is present, the wind-driven movement of pack ice against the edge of shorefast ice and ice piling against the existing barge loader during spring also can increase underwater background noise levels.

Bathymetry-Bottom Composition. In general, underwater sounds travel farther over a smooth bottom or in deep water. Underwater sounds also generally travel farther over a bottom that has exposed bedrock or gravel patches (hard surface) than over a bottom that contains mostly silt and sand (softer surface). In shallow water, the under surface of the water can provide a reflective surface for sounds to bounce off and travel a greater distance.

The eastern Chukchi Sea in the vicinity of Portsite is generally shallow, with depths of only about ~20 meters at approximately 8 kilometers offshore. The majority of the bottom is generally soft, made up of silt and fine sand with occasional patches of medium-grained sand, which would tend to reduce sound transmission. Highly reflective materials such as smooth bedrock, over-consolidated clay layers, and subsea permafrost that contribute to high levels of sound propagation (low transmission loss) are typical in the Beaufort Sea but are not found in the Chukchi Sea near Portsite. The shallow depth and soft bottom tends to decrease the distance sounds are transmitted underwater.

Literature Cited:

Blackwell citing Urick 1971. Suzanna Blackwell, PhD. Senior Scientist, Greeneridge Sciences, Inc. citing Urick, R. 1971. The noise of melting icebergs. J. Acoust. Soc. Am. 50(1, Pt. 2): 337-341.